Assessing the Evolution of Convection in High-Resolution Model Simulations over the Southeastern United States Using GOES-16 Satellite Observations

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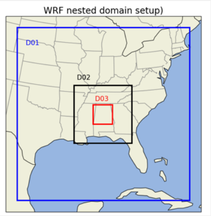
Background

High-resolution NWP models are often combined with observational analysis to understand the physical processes in the early stages of convective initiation (CI) that may develop into severe weather. Model forecasts are highly influenced by the choice of parameterization schemes. Before the information content from NWP simulations can be applied to satellite and radar observations we must first investigate model accuracy in the development of CI.

- Object-based analysis has been shown to be useful when validating cloud structures from NWP simulations. We have developed an object-based methodology to evaluate simulated CI events commonly found across the Southeastern United States.
- Composite analysis of observed and simulated CI events allows the assessment of bulk cloud characteristics without worrying about the cloud spatial and temporal variability. We utilize observation-based forecast metrics commonly implemented to forecast CI using brightness temperatures (T_b) from GOES-16.

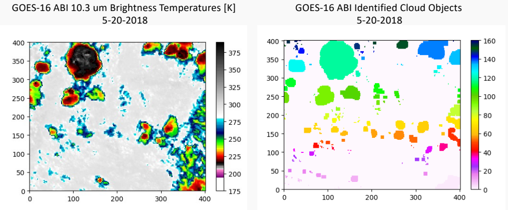
Analysis Methods and Object Tracking


WRF nested domain setup)

- Similar to Mecikalski et al (2006), convective initiation is defined when the radar reflectivity within a cloud object exceeds 35 dBz, which typically occurs just before a storm produces lightning.
- A suite of WRF simulations was run, with the domain centered over the Alabama/Mississippi border. GOES-16 ABI and Level 2 NEXRAD radar data are collocated within this region for comparison.

- For this work, we compare output from simulations run using the Thompson and Morrison cloud microphysics schemes, and the Unified Noah and Noah-MP LSM.
- Simulated brightness temperatures for the 10.3 μm clean IR channel and the 6.2 μm water vapor channel are derived using the Community Radiative Transfer Model (CRTM) for each simulation.
- CI forecast metrics, such as system size (using 10.3 μm) and cloud height (6.2μm – 10.3 μm Tb difference) will be used in a composite analysis from a May 20th, 2018 case study where hail and wind damage were reported.

Example of object identification using Brightness Temperatures over Alabama


GOES-16 ABI 10.3 um Brightness Temperatures [K]
5-20-2018

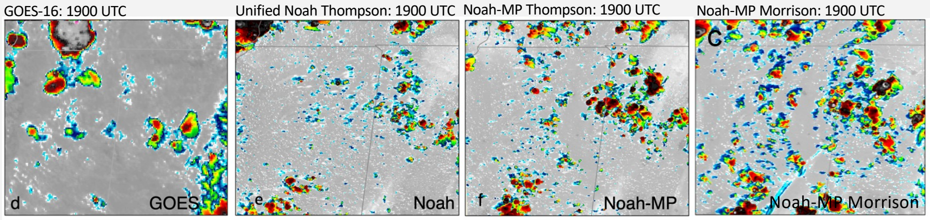
GOES-16 ABI Identified Cloud Objects
5-20-2018

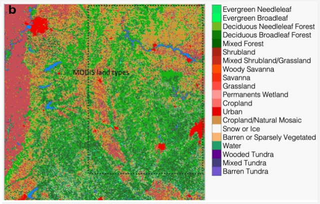
Cloud Object Tracking

Cloud objects are filtered using brightness temperatures less than 280K and defined using a methodology similar to Fiolleau and Roca (2013) to define cloud objects; it initiates object detection at colder T_bs to help separate convective regions.

- Objects are identified for both observations and models at 5-min intervals and tracked through time using the SciPy Python labeling package.

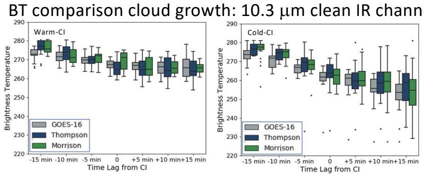
Observed and Simulated Cloud Top Brightness Temperatures


GOES-16: 1900 UTC
Unified Noah Thompson: 1900 UTC
Noah-MP Thompson: 1900 UTC
Noah-MP Morrison: 1900 UTC

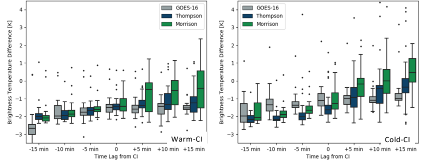


Evaluating Impact of Microphysics on CI Growth

BT comparison cloud growth: 10.3 μm clean IR channel

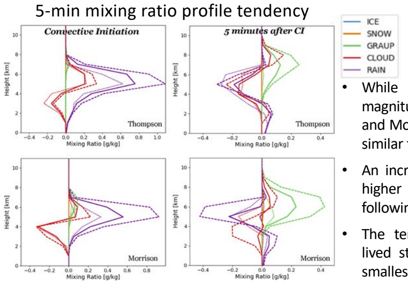


Cloud-top glaciation: 6.2μm – 10.3 μm



- Box-and-whisker diagrams comparing observed and simulated (top) IR growth rates and (bottom) cloud top glaciation signals Cold-CI is defined as CI cloud tops growing colder than 250 K. Time zero is when CI was detected.

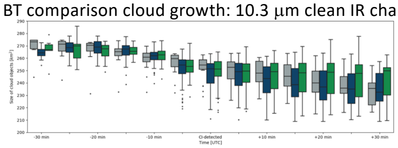
5-min mixing ratio profile tendency



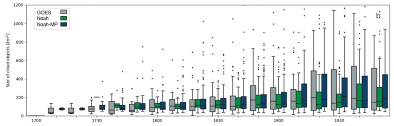
- While mixing ratio profile magnitudes differ, both Thompson and Morrison schemes demonstrate similar tendencies.
- An increase in rain at CI results in higher ice/graupel immediately following CI detection.
- The tendency increases in longer lived storms (dashed lines) and is smallest in warm CI clouds (dotted).

Evaluating Impact of Land Surface Model on CI

BT comparison cloud growth: 10.3 μm clean IR channel

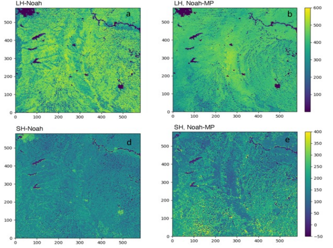


Timeseries of CI cloud object size distribution

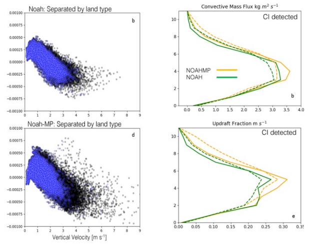


- (top) Box-and-whisker diagrams comparing observed and simulated (top) IR growth rates 30 minutes before and after CI was detected.
- (bottom) The distribution of observed and simulated cloud object size for active CI clouds over three hours (1700 UTC-2000 UTC)

LSM latent and sensible heating



LSM divergence and updraft characteristics



The changes in convective growth are largely related to the partitioning between surface SH and LH fluxes. The higher SH from Noah-MP LSM resulted in increased surface convergence, which resulted in higher peak vertical velocities. The strongest low-level convergence and upward vertical velocities occurred in the Noah-MP experiment

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Relevant References

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